US006883247B2

(12) United States Patent
Barrett

(10) **Patent No.: US 6,883,247 B2**
(45) **Date of Patent: Apr. 26, 2005**

(54) GAS DELIVERY SYSTEM

(76) Inventor: **John F. Barrett**, 7140 Java Dr., Sarasota, FL (US) 34241

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/691,953**

(22) Filed: **Oct. 23, 2003**

(65) **Prior Publication Data**

US 2004/0079226 A1 Apr. 29, 2004

Related U.S. Application Data

(62) Division of application No. 09/963,915, filed on Sep. 26, 2001, now Pat. No. 6,792,846.
(60) Provisional application No. 60/235,429, filed on Sep. 26, 2000.

(51) **Int. Cl.**[7] **F26B 21/06**
(52) **U.S. Cl.** **34/72**; 34/79; 34/80; 34/526; 34/558
(58) **Field of Search** 34/72, 79, 80, 34/526, 558, 582

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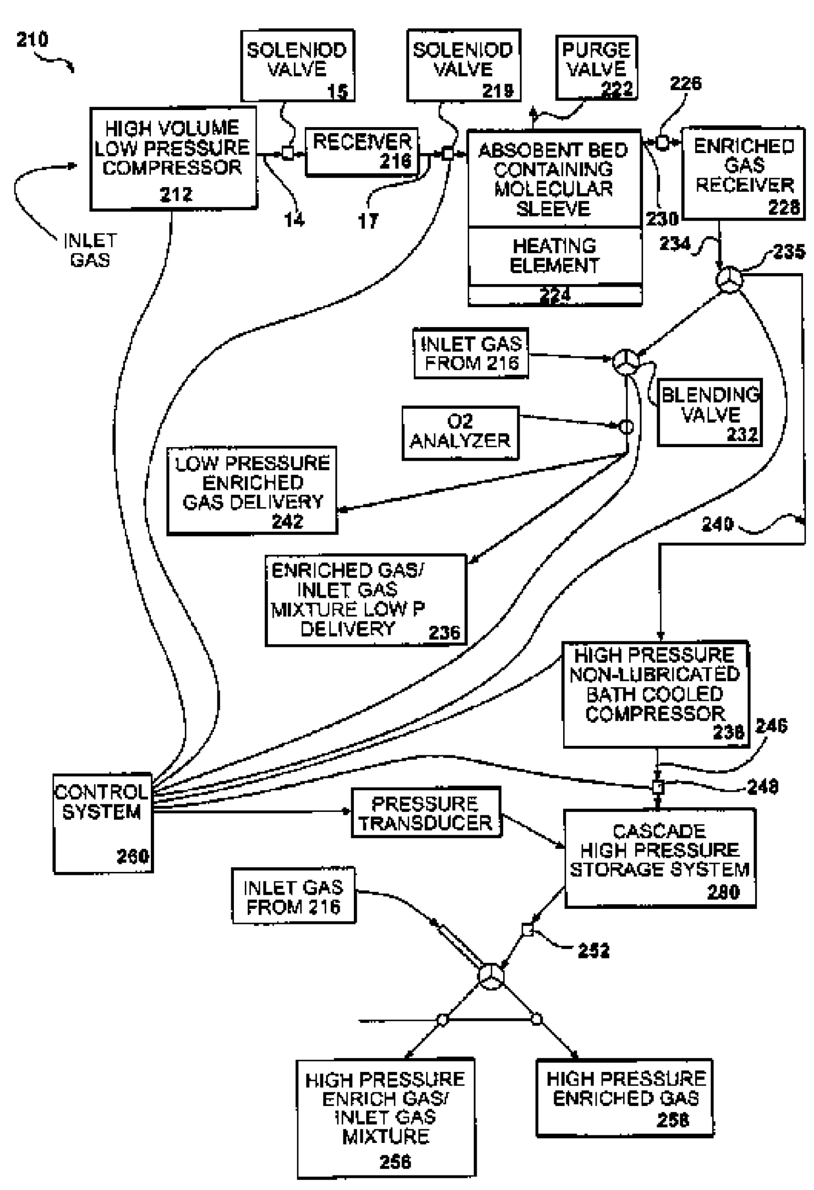
Primary Examiner—Jiping Lu
(74) *Attorney, Agent, or Firm*—Gifford, Krass, Groh, Sprinkle, Anderson & Citkowski, P.C.

(57) **ABSTRACT**

A submersible gas compressor is described which has a ceramic high pressure piston in contact with a ceramic sleeve, a drive piston mounted to the ceramic high pressure piston and a crank in mechanical connection with the drive piston. The submersible gas compressor can be used as a second stage compressor in a gas delivery system that includes a first stage low pressure compressor, an absorption bed containing molecular sieve material, a second stage compressor to pressurize a gas stream to a pressure between 5000 and 10,000 psig, a cascade system for storing the pressurized gas stream between 3500 and 5000 psig, a control system, and an outlet for delivering the pressurized gas stream.

8 Claims, 3 Drawing Sheets



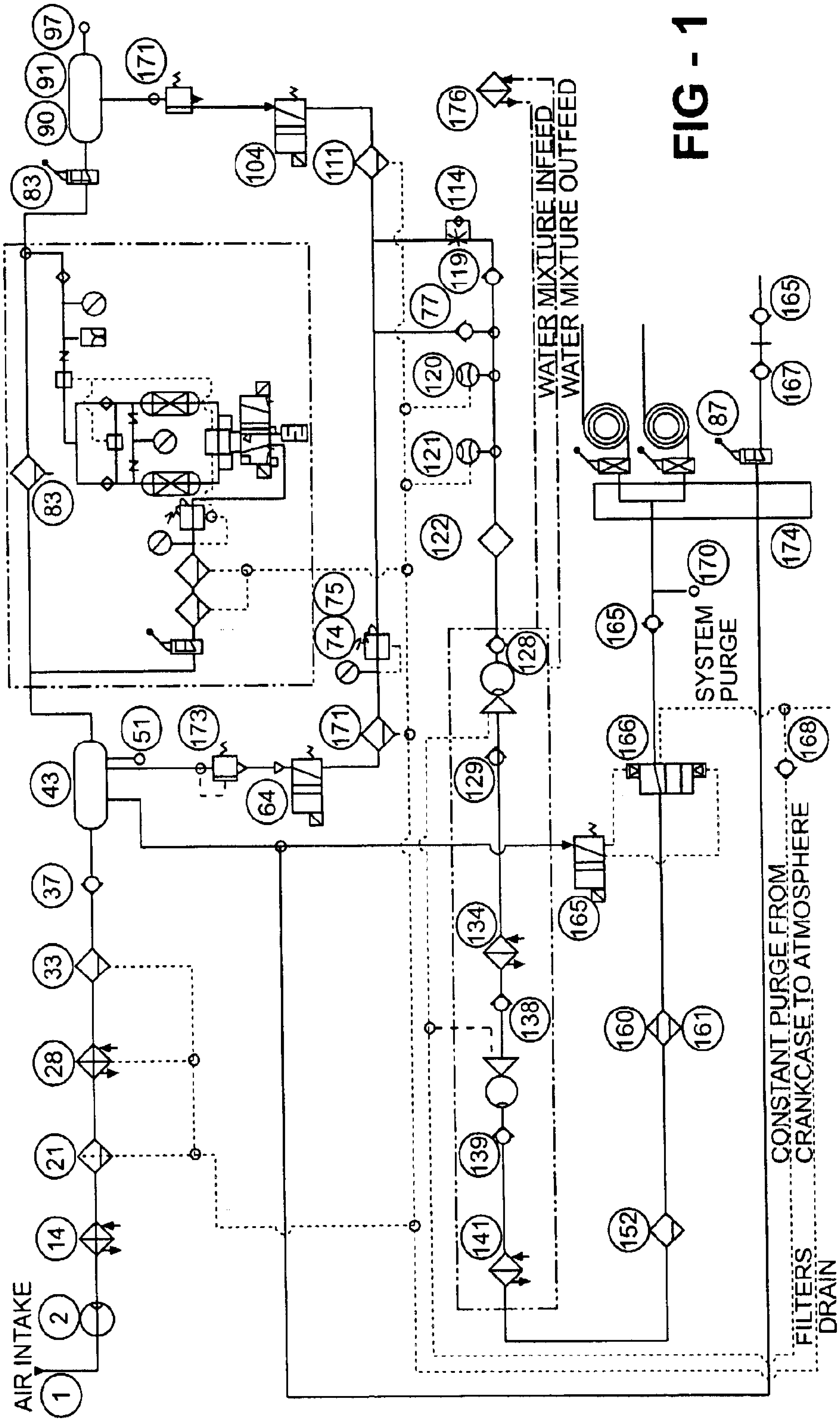

AIR INTAKE
WATER MIXTURE INFEED
WATER MIXTURE OUTFEED
SYSTEM PURGE
CONSTANT PURGE FROM CRANKCASE TO ATMOSPHERE
FILTERS DRAIN

FIG - 1

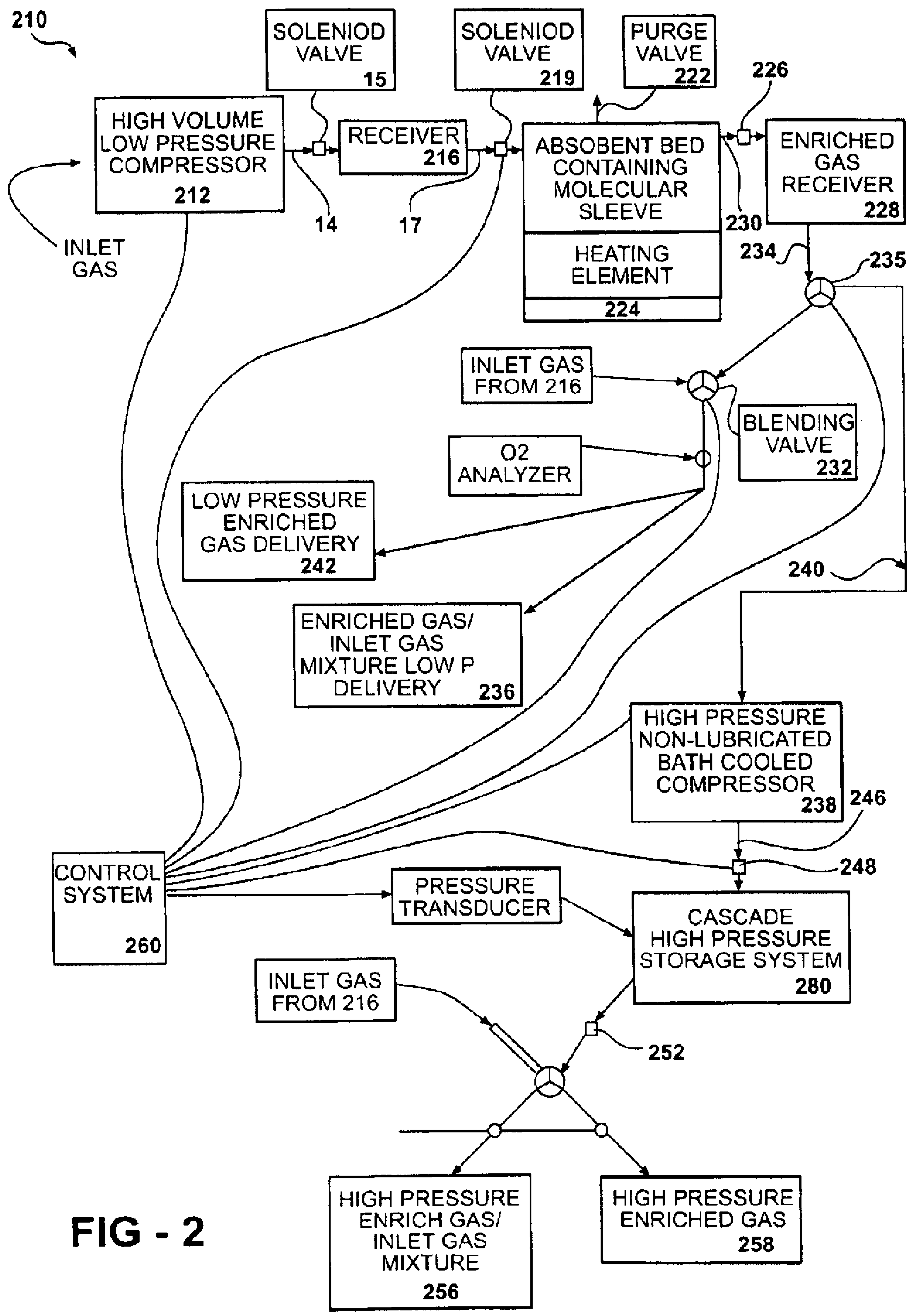

210
SOLENIOD VALVE 15
SOLENIOD VALVE 219
PURGE VALVE 222
226
HIGH VOLUME LOW PRESSURE COMPRESSOR 212
RECEIVER 216
ABSOBENT BED CONTAINING MOLECULAR SLEEVE
ENRICHED GAS RECEIVER 228
14
17
230
INLET GAS
HEATING ELEMENT
224
234
235
INLET GAS FROM 216
BLENDING VALVE 232
O2 ANALYZER
LOW PRESSURE ENRICHED GAS DELIVERY 242
240
ENRICHED GAS/ INLET GAS MIXTURE LOW P DELIVERY 236
HIGH PRESSURE NON-LUBRICATED BATH COOLED COMPRESSOR 238
246
248
CONTROL SYSTEM 260
PRESSURE TRANSDUCER
CASCADE HIGH PRESSURE STORAGE SYSTEM 280
INLET GAS FROM 216
252
HIGH PRESSURE ENRICH GAS/ INLET GAS MIXTURE 256
HIGH PRESSURE ENRICHED GAS 258

FIG - 2

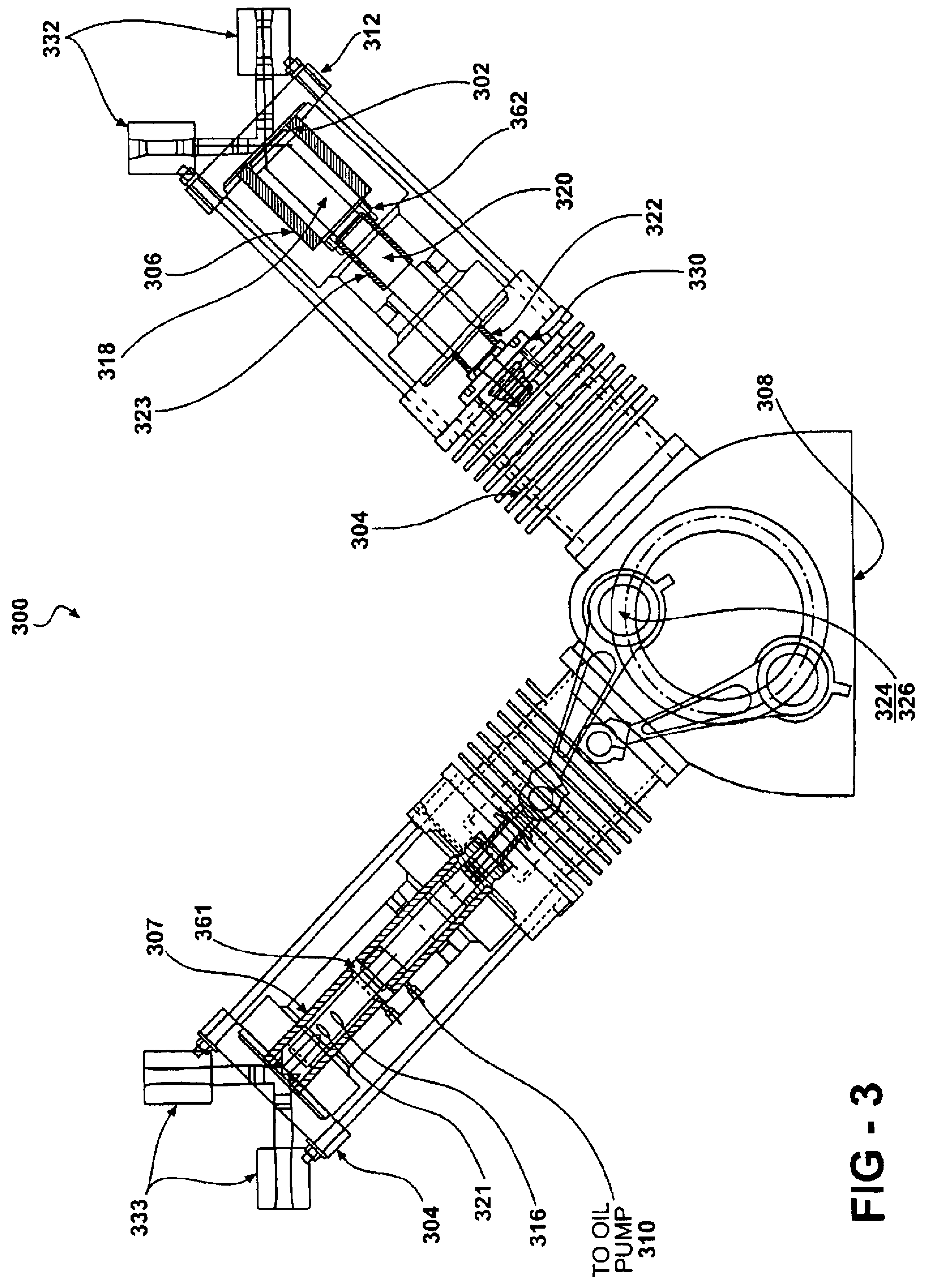

332
312
302
362
320
322
330
306
318
323
308
304
300
324/326
307
361
333
304
321
316
TO OIL PUMP 310

FIG - 3

GAS DELIVERY SYSTEM

RELATED APPLICATIONS

This application is a divisional application of U.S. Ser. No. 09/963,915 filed Sep. 26, 2001, now U.S. Pat. No. 6,792,846, which is a non-provisional of U.S. Provisional Application No. 60/235,429, filed Sep. 26, 2000, and are hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to a system for separating an atmospheric gas, purifying, compressing and storing the gas for subsequent delivery and, more particularly, to a system for compressing and storing gas at pressures of up to 5,000 psig.

BACKGROUND OF THE INVENTION

The benefits of oxygen in sustaining life beyond the obvious have been known for many years. In recent years, more and more uses of purified oxygen and oxygen enriched atmospheres has been discovered. Oxygen usage in the treatment of respiratory distress from emphysema and other pulmonary disorders has been available for many years. However, treatment of Caisson's disease with enriched atmospheres in hyperbaric chambers has led to the discovery of enriched atmosphere wound treatment at elevated pressures. Day after day, the benefits of oxygen have been discovered from medical applications to aquaculture, disinfecting, cleaning and sanitizing and nutrition. Purified oxygen has been available from large suppliers who have placed large manufacturing facilities throughout the country and world in order to deliver special gases including oxygen. These facilities have barely addressed a portion of the global demand for oxygen. Areas where the infrastructure is challenged must do without the benefits of oxygen or pay a high price to obtain the needed gas.

A system that can remove the oxygen from the air, purify it, safely compress it to a level in which it can be stored either in a cascade system for distribution within a medical facility or into portable containers for transportation is needed. This system should also have the capability to continuously monitor the gas and the concentration it will be blending the gas with other gases. Today, the compression of oxygen has been limited to extremely expensive high volume systems used by the cryogenic companies or to small air cooled compressors. The latter with extreme danger due to materials compatibility and heat generated. These smaller systems also are only capable of compressing to less than 2,700 pounds per square inch due to these situations.

Oxygen generation has been available for many years. However, the ability to economically compress the gas to a level to store it for later use has not been available. Once the gas reaches a certain pressure, the gas becomes unstable due to the temperature developed reaching those pressures. The natural gas laws state that the temperature will rise as work is put into the compression of the gas. This added temperature comes from the excitation of molecules from the added work, from the friction of the mechanical process and the friction of the gas passing through an orifice. This temperature will build until the system reaches equilibrium through heat dissipation or the gas will super heat. The faster the heat is removed, the more efficient and safer the system will be. Current compression systems remove the heat using convection. That is heat removal using forced air.

Thus, there exists a need for a system that efficiently compresses and stores gas at a pressure higher than the conventional transport bottle pressure of about 3,000 psig and is able to deliver low pressure inlet gas, low pressure purified gas, high pressure purified gas, high pressure inlet gas or mixtures thereof through blending.

SUMMARY OF THE INVENTION

A submersible gas compressor is provided having a ceramic high pressure piston in contact with a ceramic sleeve, a drive piston mounted to the ceramic high pressure piston and a crank in mechanical connection with the drive piston.

A gas delivery system is provided including a first stage low pressure compressor to pressurize an inlet gas, an absorption bed containing molecular sieve material connected to the first stage compressor so that compressed inlet gas comes in contact with the absorbent bed material and is enriched in at least one component present in the inlet gas yielding an exit gas, a second stage compressor immersed in a liquid heat transfer fluid, the second compressor compressing the exit gas to a pressurized gas stream having a pressure between 5000 and 10,000 psig, a cascade system for storing the pressurized gas stream between 3500 and 5000 psig, a control system in control of at least one of the first compressor, the absorbent bed, the second compressor and the cascade system, and an outlet for delivering the pressurized gas stream.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a schematic showing an example of a delivery system according to the present invention;

FIG. **2** is a block diagram schematic showing a delivery system according to the present invention; and

FIG. **3** is a partial cutaway side view of a compressor according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is detailed with respect to a gas delivery system for separating, purifying, compressing and storing the atmospheric gas oxygen. It is appreciated that other inlet atmospheric gases are readily separated, purified, compressed and stored according to the present invention as well. Further, gas feed stocks other than atmospheric air are readily delivered according to the present invention. While the following description specifically pertains to oxygen, it is appreciated that the present invention is also operative with other gases illustratively including nitrogen, argon, helium, carbon dioxide, carbon monoxide, hydrogen, acetylene and other gaseous mixtures.

A delivery system according to the present invention is shown generally at **210** in FIG. **2**. Inlet gas air is input into a high volume, low pressure compressor **212** having an output pressure of from about 100 to 500 psig. The air compressor **212** feeds pressurized air through a conduit **214** through a solenoid valve **215** to receiver **216** for storage at from about 20 to 100 psig. The receiver **216** is in fluid communication with an absorption bed **218** by way of a conduit **217** and a valve **219**. A molecular sieve **220** or similar substance is incorporated within the bed **218** and is selected for the ability of absorbing feedstock gases in the supplied inlet gas stream without chemical reaction such that the desired enrichment gas has a preferentially low absorption. In the case of oxygen selection, suitable molecular sieve materials illustratively include pelletized zeolite type 5A as well as other molecularly selective media. The absorption bed **218** is included within a pressure suitable container typically manufactured from steel. Gas exiting the absorption bed **218** typically is about 93% oxygen and 7% noble gases including argon and helium based upon an ambient atmosphere feed gas. The absorption bed **218** is provided with a purge valve **222** and a heating element **224**. The purge valve **222** and heating element **224** being utilized to regenerate the molecular sieve **220** after prolonged usage. A solenoid valve **226** meters oxygen enriched gas into a low pressure oxygen storage receiver **228** by way of a conduit **230**. It is appreciated that an optional second absorption bed (not shown) is piped in series with the absorption bed **218** to provide a further oxygen enriched gas stream to the low pressure oxygen storage receiver **228**. Through the use of multiple absorption beds, oxygen concentrations exceeding 99 total molar percent are readily attained. A blending valve **232** is connected by way of conduit **234** and valve **235** to the low pressure oxygen storage receiver **228**. The blending valve **232** also intakes ambient air inlet gas or gas stored within receiver **216** to provide oxygen enriched breathing air **236** as an output product as required. The oxygen enriched gas stored within low pressure oxygen storage receiver **228** is typically stored at a pressure between 45 and 55 psig. The gas within receiver **228** not blended with air and outputted as enriched breathing air **234** is shunted to a high pressure stage compressor **238** by way of conduit **240**. The high pressure compressor **238** is detailed with greater specificity in FIG. **3** and is characterized as having a composite material construction that is bath cooled and operates independent of liquid lubricants. The high pressure compressor **238** operates below 130° F. and is capable of compression to 4,500 to about 10,000 psig. The output from the compressor **238** is metered through a conduit **246** by a solenoid valve **248** into a cascade system **250** for high pressure, high volume storage of gas. Storage **250** being at pressures less than the pressures outputted by high pressure compressor **238**. Thus, for example, compressor **238** operating at 10,000 psig output is stored at approximately 5,000 psig. The high pressure oxygen enriched gas within storage **250** is delivered through a blending valve **252** by way of conduit **254**. Blending valve **252** also intakes ambient atmosphere or gas from receiver **216** to selectively deliver high pressure oxygen enriched air or when no air is input, high pressure oxygen **258** is delivered. The high pressure compressor stage **238** according to the present invention provides improvements over conventional high pressure compressors in operating at a lower number of revolutions per minute (rpm) with fewer stages to yield comparable volumes and pressures as compared to conventional high pressure compressors. As a result of the lower rpm generated by a high pressure compressor according to the present invention, noise levels of less than 70 decibels are noted for a compressor capable of delivering 10,000 psig as compared to a conventional compressor of the same output which typically operates in excess of 120 decibels. The reduced size, complexity, and operating noise of the present invention makes on site delivery of variable pressure and enriched gas products available on site in facilities such as hospitals, factories, waste treatment plants and the like. A control system **260** continuously operates and monitors the process of the instant invention. The control system **260** receives input from oxygen concentration sensors and pressure monitors throughout the system **210** and operates the valves, regulates compressor speeds and the like.

The present invention is a self-contained oxygen generation, compression and storage system. The system upon attachment to electrical power begins storing oxygen. The system is intended to free facilities from the delivery of oxygen and the reliance on suppliers and produce oxygen at a lower cost.

Once attached to electrical power, the computer control system **260** energizes and allows a user to determine the product and concentration required. Once the user initiates the process, the system begins by compressing air, filtering the air and storing the air in the receiver 15 to 125 psig. The absorption bed **218** requires a large volume of pressurized air to supply the molecular sieves **220**. Since air is approximately 20% by volume oxygen, the sieves **220** discard nearly 80% of their supply as unusable. As the gas flow exits the absorption bed **218**, the output is 93% pure oxygen with the trace noble gases remaining. This gas flow exits at a pressure of approximately 40–50 psig. The gas is stored in the receiver **228** at that pressure. From the receiver **228**, the gas is sent to a high-pressure compressor **238**.

Divers and fire fighters typically use this blend in portable breathing devices. The nitrox blending is close loop computer controlled and monitored with analyzers **262** to continuously audit the mix purity.

A high pressure compressor according to the present invention **300** is shown in FIG. **3**. A high pressure piston **302** rides on a piggyback drive piston **304**. To assure long life of the compressor **300**, a piston shaft **306** is run through at least two liner bushings **322** and **323** equipped with oil grooves ported specifically for the return of oil to a crankcase **308**. The liners **322** and **323** are fed oil through a high pressure gear pump **310** having an oil filter generating oil pressures in excess of 300 psig. Compressor heads **312** and **314** include check valve cartridges **332** and **333**, respectively. The check valve cartridges according to the present invention facilitate cleaning to a high period of gas delivery as well as field repair and maintenance. Copolymer wipers **361** and **362** are provided to create a barrier preventing oil and contaminants from entering the compression chambers **316** and **318**, respectively. The copolymer wipers **361** and **362** are formed from a variety of polymeric materials illustratively including glass filled Teflon with stainless backup rings. The compression chambers **316** and **318** are defined by composite material cylinder sleeves **320** and **322**. Preferably, piston components contacting the cylinder sleeves are formed of the same composite material. The composite material is selected to demonstrate high temperature stability, durability, chemical resistance and the ability to operate absent a liquid lubricant. Composite materials suitable for cylinder sleeve and piston manufacture illustratively include complementary grades of alumina oxide. Preferably, a cylinder sleeve and piston are machined in a matching set in order to obtain precision fits and seal.

The high pressure compressor design according to the present invention is designed for submersible mounting within a coolant tank (not shown) wherein the compressor drive remains outside of the tank. The tank has interfacial seals which keep water within the tank and allow the water to circulate freely around the compressor **300** in order to keep the compressor block **220** cool in addition to the heat exchanger **322**.

A compliant coupling **330** mounts between the drive piston **304** and the high pressure piston **302**. The compliant coupling **330** allows the drive piston **304** to move while the pressure piston **302** is securely and accurately guided within the cylinder sleeve **306**. Compliant coupling **330** serves to reduce wear between the piston **302** and the cylinder sleeve **306**. The crank **324** has a double hung shaft **326** obviating a cantilever action on the crank **324** during compression cycles. The compressor **300** according to the present invention preferably operates at a speed of between about 600 and 800 rpms. More preferably, the compressor **300** operates at about 600 rpms, which is approximately one-third the speed of conventional compressors.

This along with about eighty feet of high-pressure heat exchanger tubing keeps the oxygen at a safe temperature during the compression. In the rare event of a flammable gas leak from the present invention, the possibility of flash will be minimized due to the submerged design. During this process, the gas will pass through and be sampled by a set of analyzers that will be monitoring the concentration of oxygen, presence of carbon monoxide, water vapor and carbon dioxide. The computer control system **360** also reports through an operator touch screen interface (not shown) the results while storing the data. A modem system is optionally incorporated into the system to allow periodic off site monitoring of the system and the process from the manufacturer.

The output of the compressor will be directed to a bank of cascade high-pressure storage tanks. The tanks will supply the users with the necessary volume. In most cases, the remote locations requiring oxygen can now have what they need when they need it. This will come at a fraction of the cost of delivery.

EXAMPLE

A schematic of an embodiment according to the present invention is shown at FIG. **1**. FIG. **1** index numbers correspond to the following components:

An air intake filter **1** such as that furnished General Air (Rotary Air), filters air that is then conducted to a low pressure compressor **2**, such as #AM7.5HD-60/3 provided by General Air (Rotary Air). The low pressure compressor **2** produces relatively low pressure compressed air, in the range of 90 to 500 psig, that is subsequently directed to an aftercooler **14**, such as that furnished by General Air (Rotary Air). The aftercooler is connected to a filter **21**, such as HN2S-3PUA supplied by General Air (Parker), for removal of particulates. Following filtration air is directed to a dryer **28**, such as DE102 from General Air (MTA) and a coalescing filter **33**, such as HN2S-10CA before reaching a check valve **37**, such as 00339 3003 from Parker, and then a receiver **43** such as a 30 gallon receiver, GB-30, supplied by General Air. The receiver **43** is in communication with a 0–200 transducer **51**, for example that commercially available from Instrument Specialties as #LMV-200. The receiver **43** has connections to several air pathways. In a first alternative route, the air can be directed to a branched path wherein a first branch leads to a three-way solenoid valve **165**, such as that available commercially from Silliman (TPC) as DX2-FG-S1SSUA03, followed by a high pressure air pilot purge valve **166** such as that available from Autoclave as SW6075-OM. The purge valve opens to a system purge and check valve **168** and, alternatively, to a check valve **171**. Connected to the check valve **171** is an air pathway, with a connection to a 0–5000 PSI transducer, such as that from Instrument Specialties #LMV-5000. The air pathway is connected to a distribution manifold **174** which may be from Dynax, Inc., #316 stainless steel for example. The second branch of the branched path is connected to a locking ball valve **87** and to relief valves **167** and **169**.

A second alternative route for air leaving the receiver **43** is via a 3-way solenoid valve **64**. The solenoid valve is connected to a coalescing filter **71**, such as model #HN2S-6A available from General Air (Parker) which is connected to a pressure regulator with a gauge **74**, such as #1274G-3AT-RSG obtainable from Norgren. The pressure regulator is in communication with a check valve **77**, which may be #00339 3002 sold by Parker. Connected to the check valve **77**, is an oxygen analyzer, **120**, which is connected to a carbon monoxide sensor **121**, which is in turn connected to a relative humidity sensor **122**. The analyzer, CO sensor and the humidity sensor used may be of the types available from Instrument Specialties as #XM02-2L-11(XCAL-41), #A-TOX-11-BM-MO-10-000-0 and #CMS-1-1-1, respectively. The humidity sensor, **122**, is connected to a check valve low pressure head inlet, **128**, and the check valve, **128**, is in communication with a check valve low pressure head output, **129**, both check valves **128** and **129** are such as are available from Rego as #CG375B. Check valve **129** is connected to an innercooler **134** coil #1 and #2 such as available from Dynax, Inc. The innercooler **134** is connected to a check valve high pressure head inlet, **138**, and the check valve, **138**, is in communication with a check valve high pressure head output, **139**, both check valves **138** and **139** are such as are available from Rego as #CG375SS. Check valve **139** is connected to an aftercooler **141** coil #1 and #2 such as available from Dynax, Inc. Connected to the aftercooler **141** is a filter separator **152**, such as #4516N TF-B3 CL from Norman Filters. The filter separator **152** is connected to a filter housing **160** and a filter cartridge **161**, #s PU-530003-AF and X53249 respectively, available from Lorence Factor. The filter housing **160** and filter cartridge **161** are connected to the high pressure air pilot purge valve **166** and downstream components as described above.

A third alternative route for directing air from the receiver **43** is a branched route in which the first branch leads to an oxygen generator **83**, the oxygen generator in turn is connected to a locking ball valve **87**. The second branch of the third route leads to selective absorption bed materials, and then to the locking ball valve **87**. The valve **87** is in communication with a receiver **90**, such as the 30 gallon receiver GB-30 from General Air. The receiver **90** is connected to a 0–200 PSI transducer **97** such as LMV-200 from Instrument Specialties. The receiver **90** is connected to a check valve **171**, such as CG375SS available from Rego. The check valve **171** connects to a 3-way solenoid valve **104** which connects to a coalescing filter **111**. The coalescing filter **111** is in communication with a blending system **114**, such as is available from Instrument Specialties as TDFXPD6000-405. The blending system **114** is connected to a check valve **119** which is in turn connected to check valve **77** and oxygen analyzer **120**. A water chiller **176**, such as RV01A1N, 140 PSI, from General Air (TPA) is provided to cool high pressure compressor system components shown generally in the box outlined in FIG. **1** which contains elements **128**, **129**, **134**, **138**, **139** and **141**.

The present invention has been described with reference to preferred embodiments. It is appreciated that there will be modifications to the present invention that fail to depart from the spirit thereof as detailed herein. Such modifications are intended to fall within the scope of the appended claims.

What is claimed is:

1. A gas delivery system comprising:

a first stage compressor pressurizing an inlet gas to between 90 and 500 psig;

a first absorption bed comprising a molecular sieve material in fluid communication with said first stage compressor, said absorbent bed enriching an exiting gas stream in at least one inlet gas component;

a second stage compressor immersed in a liquid heat transfer fluid, compressing the exiting gas stream to a pressurized gas stream having a pressure of between about 5000 and 10,000 psig;

a cascade system for storing the pressurized gas stream at a pressure between about 3500 and 5000 psig;

a control system in operational control of at least one of said first stage compressor, said absorbent bed, said second stage compressor and said cascade system; and

an outlet for delivering said pressurized gas stream.

2. The gas delivery system of claim **1** wherein said molecular sieve is type 5A and said at least one inlet gas component is oxygen.

3. The gas delivery system of claim **1** further comprising a blending valve interspersed between said absorbent bed and said second stage compressor for delivering in combination the exiting gas stream and the inlet gas.

4. The gas delivery system of claim **1** further comprising at least one monitoring device selected from the group consisting of: pressure gage, oxygen concentration gage, and thermocouple, coupled to said cascade system and providing data to said control system.

5. The gas delivery system of claim **1** further comprising a blending valve in fluid communication with said outlet and the inlet gas for delivering in combination pressurized gas stream and outlet gas.

6. The gas delivery system of claim **1** further comprising a second absorption bed.

7. The gas delivery system of claim **6** wherein the first absorption bed is connected in series with the second adsorption bed.

8. The gas delivery system of claim **6** wherein the first absorption bed is connected in parallel with the second adsorption bed.

* * * * *